International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249–6890; ISSN(E): 2249–8001
Vol. 10, Issue 1, Feb 2020, 385–396
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COMPUTATIONAL FLUID DYNAMICS INVESTIGATION OF STATIC CONDITIONAL FLAPPING WING MICRO AIR VEHICLE

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ABSTRACT

The flapping wing Micro Air Vehicle (MAV) is an emerging technology with ongoing investigations and researches. The research in flapping wing concept vehicles is still lagging in their performance and stability.Unsteady aerodynamics behaviors are challenging to maintain the MAV's maneuverability in the air. This research helps to do further development researches in the MAV. This study is directed in the static conditional performance of the micro air vehicle. The CATIA designing software designs the structure of the micro air vehicle. Wing shape is its own configured, and angles are changed from 0 to 15 degrees for finding better performance in the static condition. Design is analyzed by the Computational Fluid Dynamics (CFD) for finding the vehicle's lift, drag, pressure distribution, velocity contour, and streamlines.

KEYWORDS: Flapping wing Micro Air Vehicle, Unsteady Aerodynamics & Computational Fluid Dynamics

Received: Oct 16, 2019; **Accepted:** Nov 06, 2019; **Published:** Jan 20, 2020; **Paper Id.:** IJMPERDFEB202032

Original Article

1. INTRODUCTION

In modern days, Unmanned Aerial Vehicles (UAV) are compact vehicles for surveillance, reconnaissance, and sensing. Mostly these vehicles are operated by autonomous and semi-autonomous. These vehicles are mainly used for defense purposes. After the decades, the optimized structure is developed in the UAV, which is called a micro air vehicle (MAV). The size and weight are nearly two-digit millimeter and pounds. Defense Advanced Research Project Agency (DARPA) is responsible for the emerging technology in the surveillance-based vehicles that define the size and design structure of the MAVs. The DARPA has defined the minimum range, endurance, and speed. MAVs have three different structures based on their wing operation, which are rotary-wing, fixed-wing, and flapping wing. The rotary-wing vehicle is operated by the rotatable wing, which will produce the active forces. The additional energy sources propel the fixed-wing vehicles, and the wings do the maneuver. The flapping wing concept is similar to the humming birds and insects. This vehicle gives better performance only in the indoor operation because of its less weight. So, it is not suitable for the freestream air operations.

2. MODELLING OF MAV'S PARTS/OVERALL SYSTEM DESIGN

Designing of the MAV is challenging work because all the parts are minute level objects. So, the computer-aided designing software is preferable to designing the vehicle’s part and assemble. In this research, the CATIA designing software is used. This software provides the 2-dimensional and 3-dimensional drawing methods. It is preferable for designing and assembling the mechanical parts without any difficulty. This research concept is to reduce the MAV’s weight and shape optimization.The wingspan configured as 30 cm and weight is 28g. this vehicle is capable of vertical

takeoff and landing. So, it is preferable for in less space environment operations.

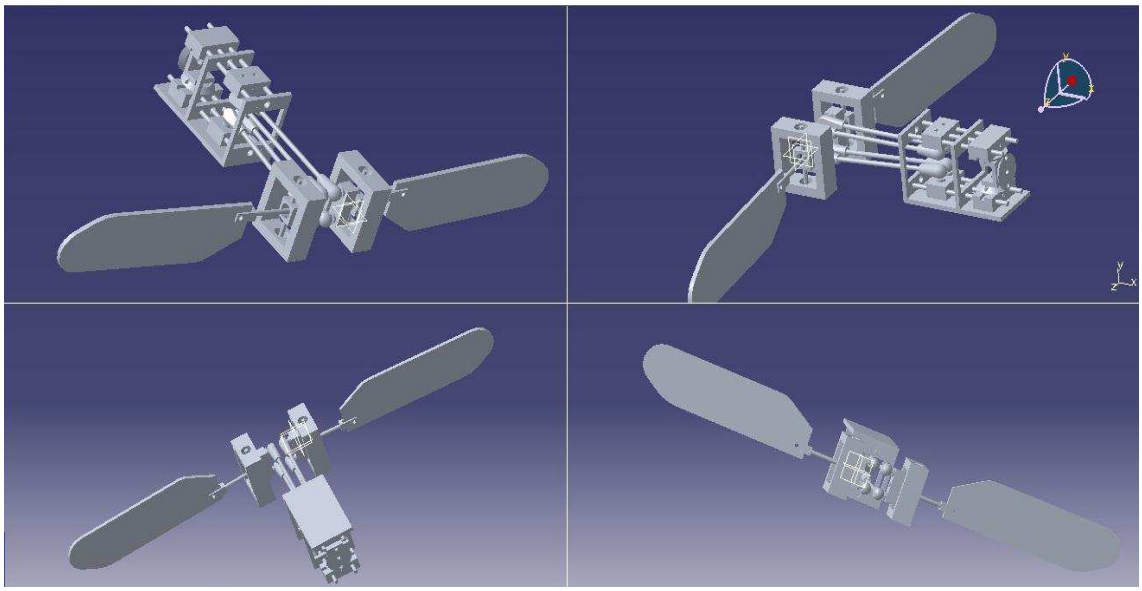


Figure 1: Micro Air Vehicle Design by CATIA Design Tool.

3. CFD ANALYSIS OF FLOW OVER FLAPPING WING MECHANISM

Computational Fluid Dynamics tool needs all the parameter values to do the simulation. So, the following aspects have to follow-up for post-processing

- Aero volume creation
- Discretization of aero volume domain
- Flow solver methodology
- Visualization of flow around the flapping wing mechanism.

3.1 Aero Volume Creation

The cubic shape domain is created around the flapping-wing micro air vehicle. This aero volume helps to find the vehicle's performance characteristics ina particular environmental condition. The volume creation has two methods; one is extracted volume another is geometry simplification. The extracted volume method helps to extract the volume for the fluid simulation and another method simplifies the solid simulation.

3.2. Discretization of Aero Volume Domain

The total volume of the aero domain is subdivided into counterparts by using ANSYS Fluent software. Each small element is the control volume in which a finite volume approach solves the flow properties. The size of the tetra cell and tri face is 0.06m and 0.03m.Discretization is a mathematical approach to get the results of a vehicle's performance characteristics.

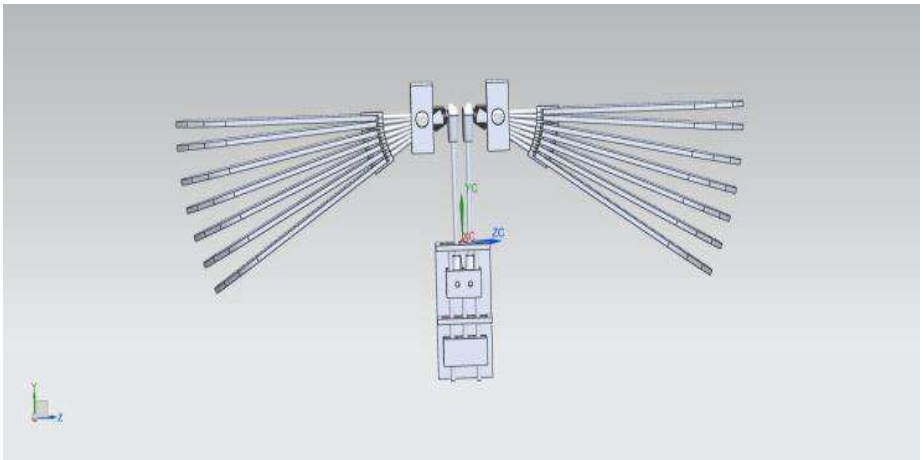


Figure 2: Micro Air Vehicle Structure in Several Angle of Attack.

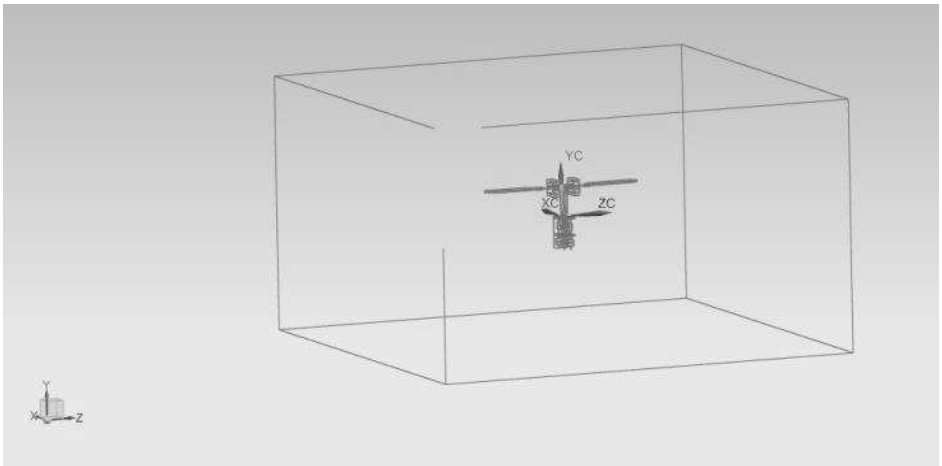


Figure 3: Aero Volume Domain Around the Flapping Wing Mechanism.

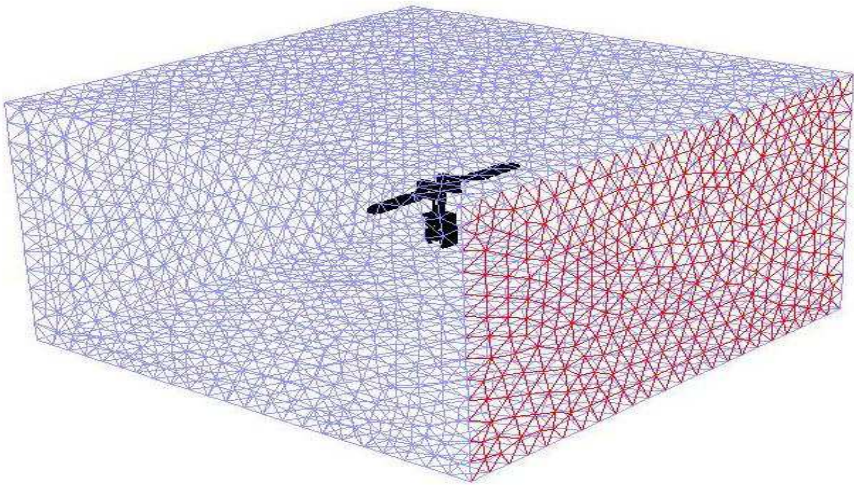


Figure 4: Discretized Aero Volume Domain.

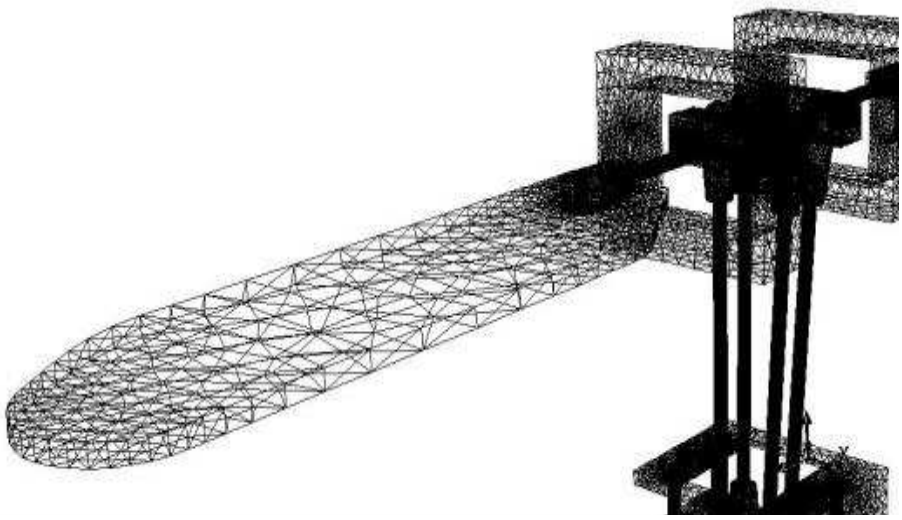


Figure 5: Tetra Mesh Over the Wall Surface.

3.3 Flow Solver Methodology

The ANSYS Fluent solver solves the flapping-wing micro air vehicle's flow analysis. This tool solves the flow conservation equations using the finite volume approach. So, this method is used to solve the flow equation on unstructured grids. Reynolds number of the flow over this vehicle is around 24,000 based on ISA of air at sea level condition and mean aerodynamic chord of MAV (35mm). This range of Reynolds number flow comes under the low subsonic region. In this Reynolds number, the flow is incompressible steady state. So, a pressure implicit coupled methodology is used. Turbulence inflow is created by using Reynolds Averaged Navier-Stocks Equation (RANS) approach. The incoming free stream velocity of air is assumed to be 10m/s. The exit boundary of this computational domain (downwash of the airstream) is set to the atmospheric pressure condition with an expected turbulence level of 10 (in terms of turbulence viscosity ratio). The solution is set to second-order upwind spatial discretization. The flow solution is iterated until it reaches the convergence level of 1e-3.

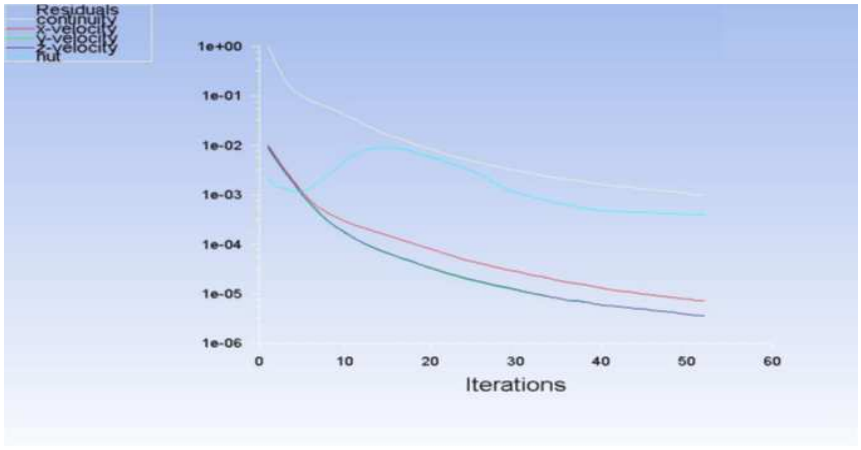


Figure 6: Convergence Solution.

3.4 Flow Pattern around the Flapping Wing Mechanism

The air flowsover the control volume wall surface, which leads to finding the reactions of the vehicle. Based on that vehicle's characteristics of lift, drag, pressure, and velocity distribution in the different angle will find.

4. PRESSURE DISTRIBUTION OVER THE WALL SURFACE ON STATIC CONDITIONAL VEHICLE

The frontal area is not a curvilinear shape, so the high pressure occurs in this area, which leads to the high drag force. The angle of attack reducesthe pressure level on the wing surface with respect to the free stream of air.

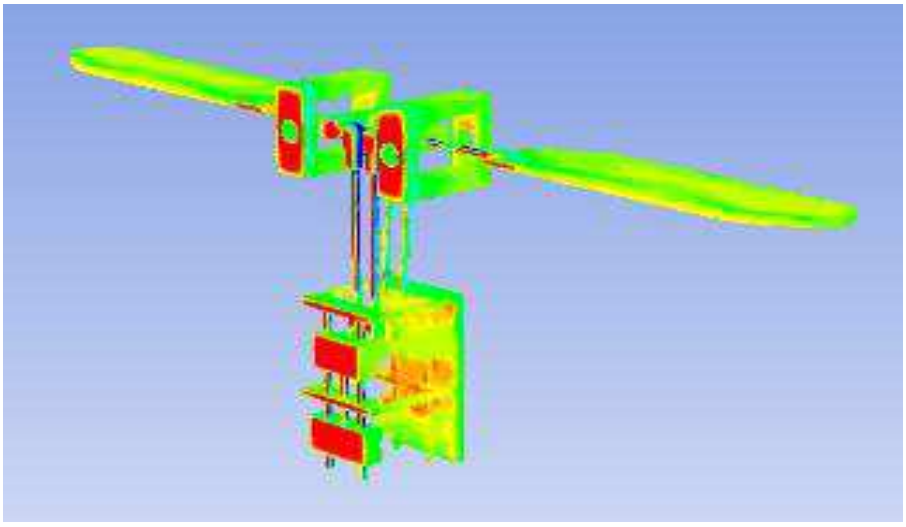


Figure 7: Pressure Distribution on the Wall Surface at the Wing Angle in 0°.

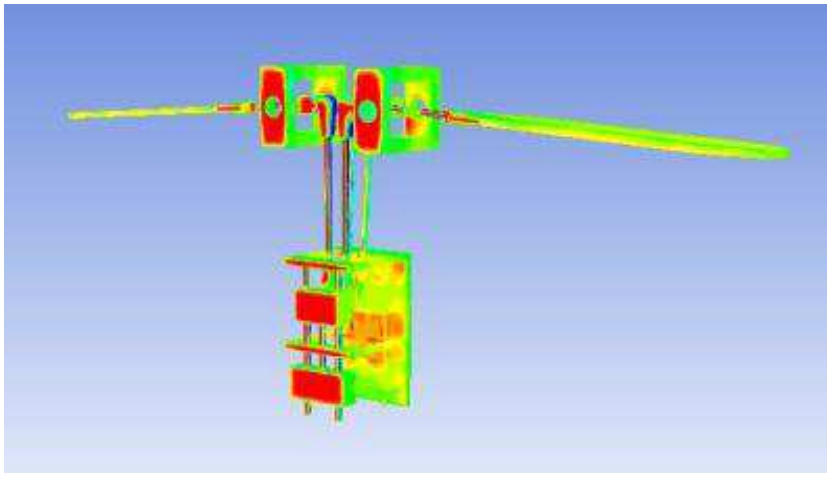


Figure 8: Pressure Distribution Over the Wall Surfaceat the Wing Angle in 5°.

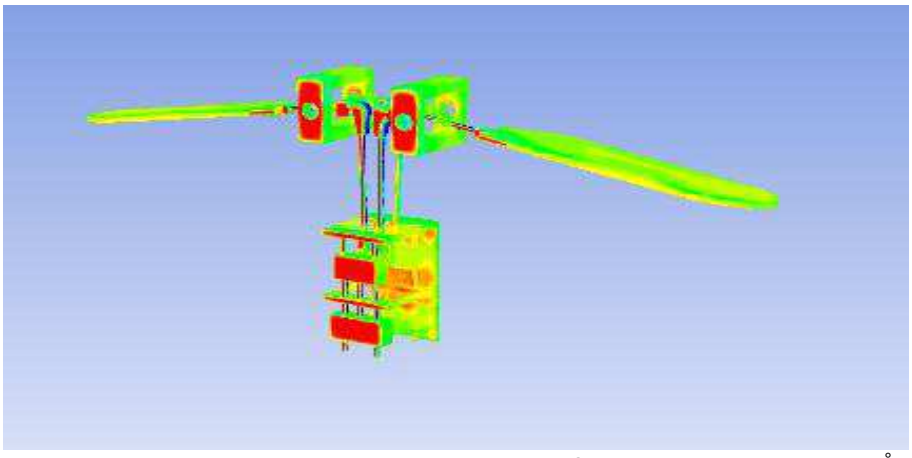


Figure 9: Pressure Distribution Over the Wall Surface at the Wing Angle in 10°.

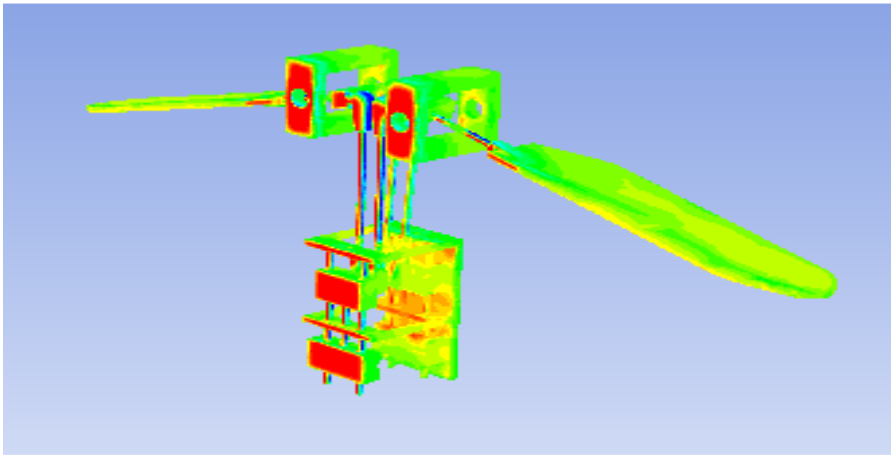


Figure 10: Pressure Distribution Over the Wall Surface at the Wing Angle in 15°.

5. PRESSURE DISTRIBUTION OVER THE MID OF PLANE

The frontal area of the surface is non-curvilinear, which is increasing the pressure level on the plane. The leading edge of the wing attains the high pressure due to its flat surface. This pressure will contribute to the drag forces. As the wind deflected, a positive angle of attack is obtained. So, pressure rises in the top and bottom of the wing. This pressure change gives a small change in the lift coefficient.

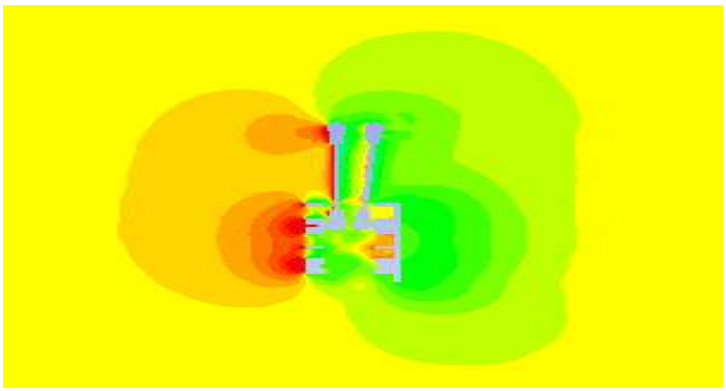


Figure 11: Pressure Distribution Over the Mid of Planeat Wing Angle in 0°.

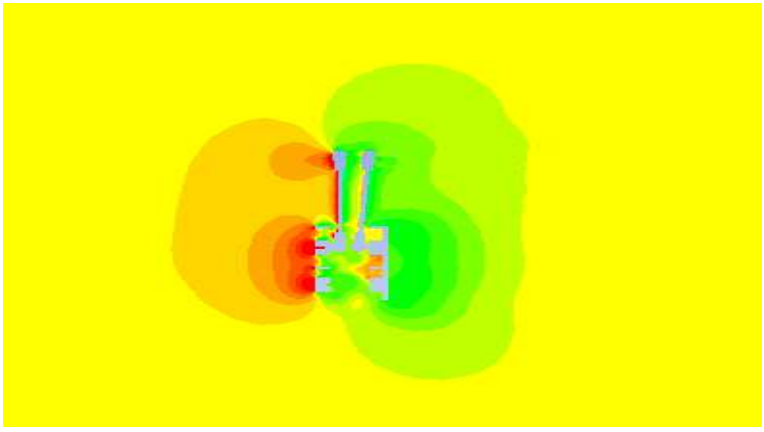


Figure 12: Pressure Distribution Over the Mid of Plane at Wing Angle in 5°.

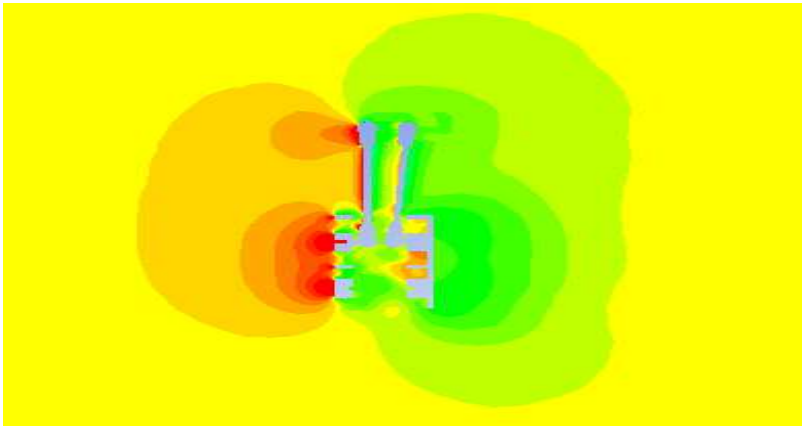


Figure 13: Pressure Distribution Over the Mid of Plane at Wing Angle in 10°

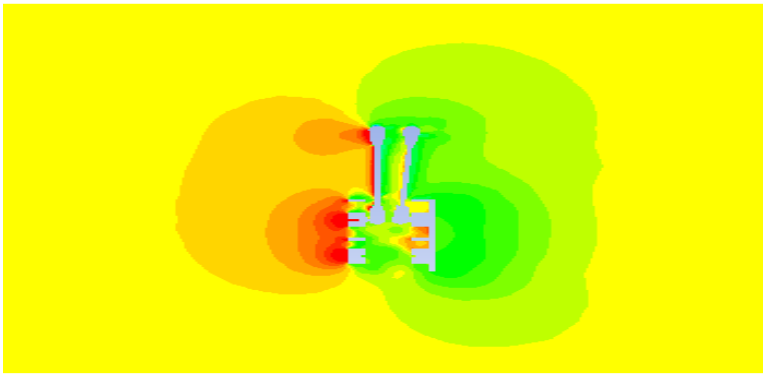


Figure 14: Pressure Distribution Over the Mid of Plane at Wing Angle in 15°.

6. VELOCITY CONTOUR OVER THE MID ISO PLANE

Wake section forms at the back of mid-body, which leads the boundary separation,and the energy is started to decreases. Nointerference drag from the wing deflection.

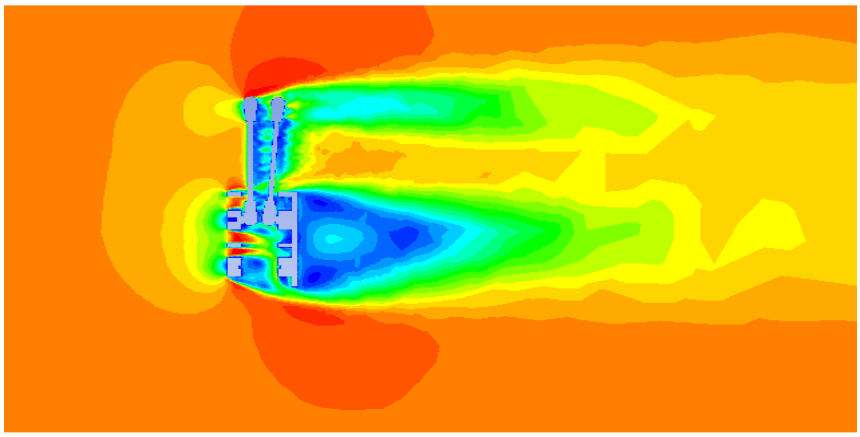


Figure 15: Velocity Contour Over the Midplane at Wing Angle in 0°.

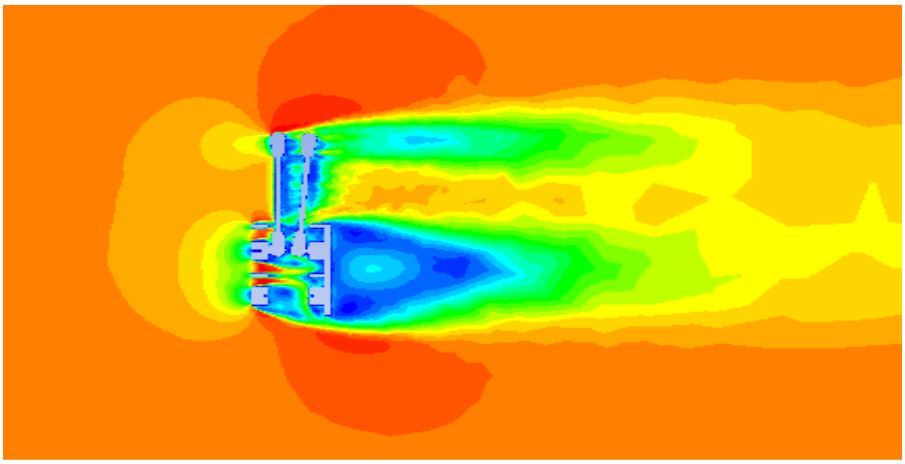


Figure 16: Velocity Contour Over the Midplane at Wing Angle in 5°.

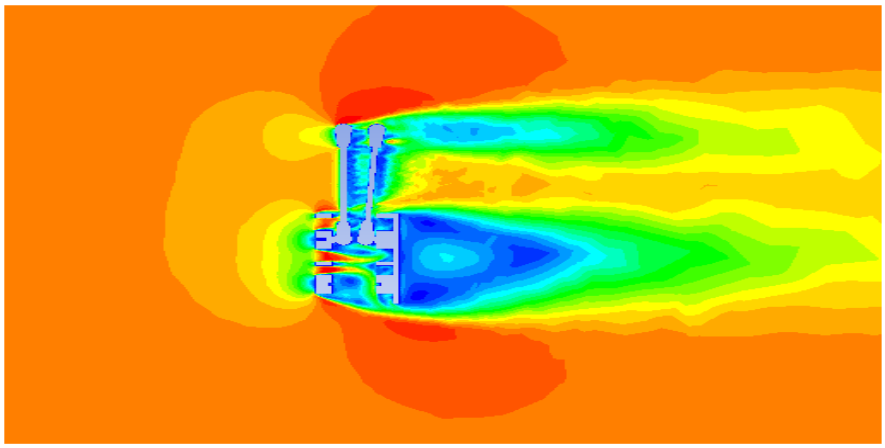


Figure 17: Velocity Contour Over the Midplane at Wing Angle in 10°.

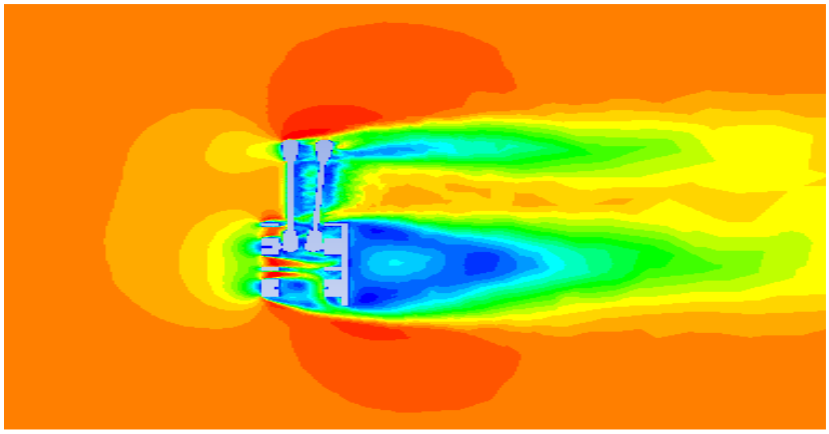


Figure 18. Velocity Contour Over the Midplane at Wing Angle in 15°.

7. VELOCITY VECTOR IN THE MID OF PLANE

The air flows inside of the midbody. However, some flow diversions are recirculated. An analytical method helps to identify the flow patterns on the selected surface.

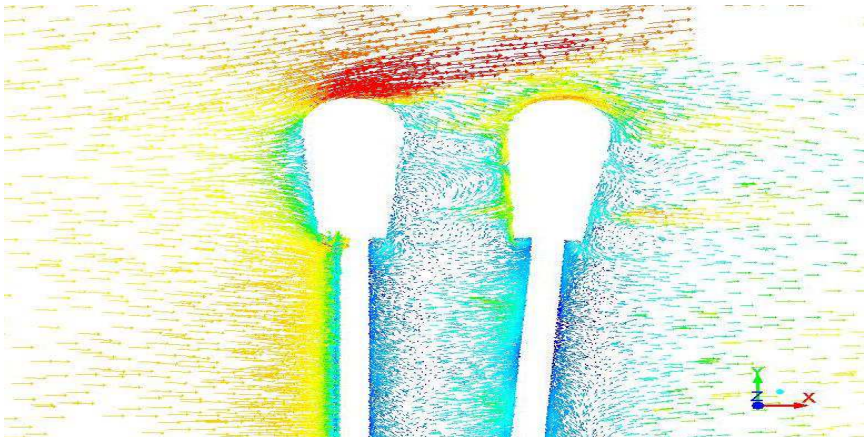


Figure 19: The Velocity Vector Over Mid of the Plane near the Top.

8. RESULTS

The different angle of attacks generates a minimum level of lift. However, the drag is obtained in all the angle of attack. The total lift is produced by the wing surface only. From this research, the static conditional micro air vehicle's lift is increased in the wing's ten-degree angle of attack, and dragalso reduced.

Table 1: Lift and Drag Variations in a Different Angle of Attack

Wing Angles(deg)	Lift	Drag
0	0.026025	0.163003
5	0.028056	0.162904
10	0.029919	0.161583
15	0.161372	0.029226

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